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A NEW RAW WATER SUPPLY FOR THE CITY OF McKEESPORT, PENNSYLVANIA

By E. C. Trax

The city of McKeesport is situated in Allegheny County, Pennsylvania, at the junction of the Youghiogheny and Monongahela Rivers, at a distance of fifteen miles by river above Pittsburgh. The population is approximately 50,000.

For twenty-seven years the source of public water supply has been the Youghiogheny River, which until 1908 was supplied in the raw state, but during the past eight years has been purified by softening and filtration. A new intake in the Monongahela River is now under construction to obtain a supply of raw water from this stream. It is the purpose of this paper to consider the circumstances and conditions which led to the abandonment of the Youghiogheny and adoption of the Monongahela River as a source of raw water supply.

The first public works to supply water to McKeesport were constructed in 1881. The works consisted of a distribution system, a reservoir on the site of the present distributing reservoir, and a power and pump plant on the east shore of the Youghiogheny River, at a point about one mile above the junction of the Youghiogheny and Monongahela Rivers. Practically all of the original distribution system is still in use; the distributing reservoir, having been enlarged and lined with concrete, and the power and pump plant, having undergone changes and additions from time to time, form parts of the system of to-day.

The water in the river was satisfactory according to the standards of those days, and the intake and pumping station were located at a point which then appeared to be the most convenient and suitable location. Owing to a lack of thorough understanding or appreciation of the influence of water supply upon the prevalence of certain diseases, and also to the fact that the river water was usually clear and free from odors and tastes, this supply was considered satisfactory for some years. While the raw water during flood stage may be very turbid, the flood waters soon run out and it is normally almost free from color and turbidity. As a matter of fact the supply was superior to certain city supplies in the vicinity until the pollution, due to industrial developments in the Youghiogheny River watershed, became unbearable. As coal mines were opened and admitted their drainage into the river, the supply became acid to such an extent that, in order to bring about some improvement, a series of wells was drilled along the river bank near the pump station. The well water was very hard, contained a large amount of iron, and was not satisfactory bacterially, but was used for many years to dilute the raw water from the Youghiogheny River, thereby decreasing its acidity. In doing this, however, the water supply to the city was increased in hardness by the influence of the water from the wells.

In Water Supply Paper 161, of the United States Geological Survey, published in 1906, it is stated: "It is evident that McKeesport is supplied with a water that is dangerous and in no sense potable or fit for consumption by human beings." The water truly merited this comment. Few municipalities have been supplied with a water as unfit for domestic and industrial uses as that supplied to McKeesport for some years prior to the construction of the water softening plant. It was at times turbid and unsatisfactory bacterially, and when perfectly clear it was corrosive and unfit even for laundry purposes on account of the high hardness, acidity and iron content.

This supply was used without treatment until 1908, and there was from time to time considerable agitation and several studies made as to improvements for relief from the then existing conditions. After investigating the merits of the various suggestions for better water it was finally decided to build a plant to purify the Youghiogheny River water. During 1907 and 1908 a purification plant was constructed on a site adjoining the pumping plant, and the well supply was entirely abandoned owing to the hardness of the water. The purification plant consists of a softening plant and mechanical filtration plant. The raw water is treated with lime and soda ash, mixed, allowed to settle, and passed through rapid sand filters. The results obtained have proven highly satisfactory, and since 1908 the city has been supplied with a water which has fulfilled in all respects the requirements of a first class water supply. The water has been soft and entirely free from turbidity, noticeable color, objectionable tastes and odors, and harmful bacteria. It is true that when a water requires heavy treatment with lime and soda ash there may be sufficient sodium sulphate formed to produce a somewhat flat or alkaline taste, to which some persons are more sensitive than others. This taste is not usually considered unpleasant and is rarely noticed by regular users of the water. In fact, after becoming accustomed to drinking softened water, it is considered by many more palatable than other supplies. The fact that the softened municipal supply in McKeesport, which is at times probably the most heavily treated domestic water supply in the world, is used almost exclusively for drinking purposes in the city is very strong proof of the potability of a softened water. It is entirely free from the earthy and fishy taste noticed in many surface supplies, and there seem to be no disadvantages or objections to the water for drinking. It is believed that in no city is the public water supply more generally used for drinking purposes and the per capita consumption of bottled table water so small.

According to the present day practice of establishing some relationship between the water supply and the total death rate, the total death rate in the city for twelve years is submitted below. This includes the six years immediately preceding and the six years immediately following the introduction of purified water.

TABLE 1

Total death rate, City of McKeesport

YEAR	DEATHS PER 1000 POPULATION	YEAR	DEATHS PER 1000 POPULATION
1903	21.4	1909	16.8
1904	21.2	1910	20.0
1905	21.8	1911	14.5
1906	19.9	1912	14.8
1907	19.7	1913	13.9
1908*	18.3	1914	11.2

* Purified water first supplied in October, 1908.

This table tends to support the theory that the general health of a community is improved by the introduction of pure water to a much greater extent than can be accounted for by the reduction in typhoid fever alone.

The experience with typhoid fever in McKeesport has been along the same lines as in many other cities where a sudden change has been made from an unpurified river water to a purified supply. An inspection of the typhoid statistics show the death rate to have been excessive in the years previous to the introduction of filtered water in October, 1908.

TABLE 2

Death rate from typhoid fever, City of McKeesport

YEAR	TOTAL NUMBER OF CASES	DEATHS PER 100,000
1900		69
1901		81
1902		87
1903		120
1904		129
1905		63
1906	512	115
1907	330	73
1908*	230	68
1909	128	18
1910	165	21
1911	51	14
1912	41	7
1913	29	5
1914	22	12
1915	26	9

* Purified water first supplied in October, 1908.

These data are included to show that the present supply is safe and highly satisfactory, and for this reason the obtaining of another supply of raw water has been delayed. It has been a case of letting well enough alone.

The Youghiogheny River, the largest tributary of the Monongahela, is about 125 miles in length and drains an area of approximately 1800 square miles. It rises in Preston County, West Virginia, and flows in a general northerly direction, emptying into the Monongahela at McKeesport. The watershed is mountainous, and the runoff is unusually large, especially of late years, as the country has largely been denuded of its forests. This results in floods and low flow in dry weather, and is partly responsible for the violent changes in flow and in the quality of the water.

The river drains a large part of the district known as the Connellsville coke region, and the activity in this vast coal and coke industry resulted in a gradual increase in the discharge of acid mine wastes into the river and its tributaries as more mines were opened. Drainage from coal mines is almost invariably highly mineralized; in addition to the salts of aluminum, calcium, magnesium, sodium and potassium, it usually contains considerable iron in various stages of oxidation, and free sulphuric acid formed by the oxidation of the iron pyrites which is present in varying quantities in connection with the coal veins. The following analyses represent the condition of some mine waters in this district:

TABLE 3

Analyses of mine waters

	PARTS PER MILLION			
	1	2	3	4
Silica	36	40	26	6
Iron Oxide (Fe_2O_3)	1435	286	780	2
Alumina	113		1985	1
Calcium sulphate	1470	584	1322	None
Calcium carbonate	None	None	None	70
Magnesium sulphate	970	377	310	None
Magnesium carbonate	None	None	None	23
Sodium sulphate	223	170	1150	4875
Sodium carbonate	None	None	None	816
Sodium chloride	30	44	994	320
Alkalinity				870
Free sulphuric acid	452	3667	16,400	None

Nos. 1, 2 and 4 are from mines in operation while No. 3 is from an abandoned working. No. 4 is an example of a highly alkaline mine water.

The effect of a small proportion of mine water in a stream is to lower the natural alkalinity. As the proportion increases the alkalinity is entirely neutralized and the water becomes acid. The flow of the mine drainage is much more constant than the flow of the stream, which is widely influenced by conditions of rainfall and run-off. The effect of the acid is therefore much more noticeable when the river is low and the mine water consequently less diluted with fresh water.

Manufacturing wastes from the plants connected with the iron and steel industry may at times add slightly to these conditions in the streams of this district, but it is believed that the effect of these wastes is almost negligible. It has been estimated that not more than 5 per cent of the acid-iron pollution is due to manufacturing plants.

The water in the Youghiogheny River passed through these various stages as the amount of mine water discharged on the watershed increased. At first it was only during especially low flow in the river that the water was acid at McKeesport. With the increase in the amount of mine wastes, the water has continued to increase in hardness and acidity to the present time. For a number of years the water has been acid at all times except for a few days following heavy rains when the river is high. During the course of this change in the stream a point was reached where fish could no longer live in the water, and they entirely disappeared from the river below Connellsville a number of years ago. The records show that the acidity of the river water has varied from 0 to 390 parts per million. The average reaction for fifteen years is shown below:

TABLE 4

Acidity to methyl-orange in parts per million

YEAR	MAXIMUM	AVERAGE
1901	128	37
1902	204	36
1903	145	30
1904	162	48
1905	72	27
1906	106	23
1907	65	19
1908	240	63
1909	210	31
1910	390	81
1911	180	30
1912	140	30
1913	305	34
1914	280	56
1915	170	24

Following are several analyses of the Youghiogheny River water taken during acid periods:

TABLE 5

Analyses of Youghiogheny River Water

	PARTS PER MILLION			
	A	B	C	D
Silica	21	23	14	20
Iron oxide	73	112	36	106
Alumina	55	52	23	
Calcium sulphate	440	458	194	319
Magnesium sulphate	194	207	99	156
Free sulphuric acid	240	170	110	200

Before the purification plant was constructed the corrosive action of the city supply on pumps and plumbing fixtures was so severe that at times of bad acid conditions it became almost impossible to supply water, and at one time the leakage amounted to 50 per cent of the water pumped. It has been estimated that the saving in plumbing bills alone since 1908 has resulted in an amount more than sufficient to pay the operating costs of the softening plant.

The Monongahela River rises in West Virginia and flows in a general northeasterly to northerly direction, joining the Allegheny River at Pittsburgh to form the Ohio. The total length of the stream is about 225 miles, and the drainage area above McKeesport is about 5600 square miles. In the upper portions the country is mountainous in character and the fall in the stream is very rapid; farther down the country becomes less rugged, but still remains hilly. Below Fairmont the slope of the stream is about 1 foot per mile. The river is navigable to Fairmont due to a series of locks and dams. Mining operations are greatly developed on the watershed and there is a large amount of mine wastes discharged into the drainage basin. The river water between McKeesport and Pittsburgh is acid a greater part of the time, due largely to the influence of the Youghiogheny River. An investigation of the condition of the water in the river above McKeesport was started in 1910, and since that time samples for chemical and bacteriological analyses have been taken almost daily. These records were kept to throw more light on what was then threatening to become a difference of opinion as to which water should be supplied. Even after building the softening plant no grave obstacles were in the way to prevent supplying Monongahela River water to the plant at any time that it might be desired or found to be advisable.

The results of the hardness and alkalinity, or acidity, which is recorded as negative alkalinity, determinations are summarized in Table 6.

Bacteriological analyses show greater sewage pollution than in the Youghiogheny, due to a great extent to the fact that only occasionally is there sufficient acid present to produce a germicidal effect. The number of bacteria developing at both 20° and 37° is generally much higher than in the Youghiogheny River, and presumptive tests for *B. coli* have been positive in 70 per cent of 1 cc. portions of the samples; while for the same period presumptive tests were positive in 35 per cent of the daily samples from the Youghiogheny River.

TABLE 6

Hardness and alkalinity of the Monongahela River water at the Dravosburg Bridge. Parts per million

YEAR	HARDNESS			ALKALINITY TO METHYL-ORANGE		
	Maximum	Minimum	Average	Maximum	Minimum	Average
1910	192	43	70	15	−40	5
1911	142	36	61	30	−15	11
1912	120	43	67	35	−10	9
1913	105	39	59	20	− 9	7
1914	212	44	82	18	−40	2
1915	100	37	64	35	+ 2	6

For the purpose of comparison a summary of the hardness and alkalinity of the Youghiogheny River for the same period is shown herewith:

TABLE 7

Hardness and Alkalinity of the Youghiogheny River water at the McKeesport Water Works Intake. Parts per million

YEAR	HARDNESS			ALKALINITY TO METHYL-ORANGE		
	Maximum	Minimum	Average	Maximum	Minimum	Average
1910	802	40	243	60	−390	−81
1911	510	40	128	45	−180	−30
1912	390	43	144	45	−140	−30
1913	700	45	154	10	−305	−34
1914	708	39	208	12	−280	−56
1915	504	42	141	20	−170	−24

A comparison of the tabulations showing the condition of the water in the two streams reveals a vast difference in the hardness and acidity content. While at times the Monongahela contains free acid and considerable hardening constituents, the amount of acid is comparatively small and the acid periods occur only during exceptionally dry weather, with low flow in the river.

The purification of these acid waters is beset with no special difficulties, the principal disadvantages being the great cost for chemicals and extreme variability in the mineral content of the water. The character of the water in the Youghiogheny River is changing constantly, and variations in hardness and acidity of from 100 to

300 parts per million in the course of a few hours are not unusual. The iron in solution amounts usually to from 5 to 75 parts per million, equivalent to from 1 to 22 grains per gallon of crystallized ferrous sulphate, and there is also present considerable aluminum sulphate. The usual method of treatment for clarification is therefore reversed, it being necessary to supply alkalinity in the form of lime and soda ash to neutralize the acid and precipitate the iron and aluminum. The iron and aluminum sulphates are present in large excess of the amount necessary to completely coagulate the water, and the natural result of this excessive coagulation is a high percentage of removal of turbidity and bacteria in the settling basins. This accounts in part for the high bacterial purity of the city supply since the softening plant has been in operation. It has not been considered necessary to use a germicide although chlorinated lime was applied for a time as an additional safeguard. None has been used, however, for more than four years.

Another factor which exerts a wide influence on the bacterial life is the germicidal action of the acid and iron salts in the river. Considerable sewage is emptied into the river above the water works intake, including the discharge of several sewers from the city itself, and during alkaline conditions of the water the bacterial numbers run very high with *B. coli* present in 0.01 to 0.1 cc. portions. As the water reverts to its normal condition of acidity the number of bacteria falls off rapidly and at times disappears entirely. The agar plates at 37° frequently show no growths, and about 3 per cent of the time during the past seven years no colonies developed on gelatine plates incubated at 20°. Several times sterile water has been obtained from the river, and at times of high acidity tests for *B. coli* are not positive in 10 cc. portions. These results are all the more remarkable in view of the fact that sewers from a populous district of the city flow into the river less than a mile above the water works intake and on the same side of the river.

The treatment of the raw Youghiogheny water has required at times enormous amounts of chemicals. The lime used has varied from 100 to 3800 pounds per million gallons and the soda ash from none to 7000 pounds per million gallons. The average amount used during the entire period of operation of the softening plant has been 866 pounds of lime and 1450 pounds of soda ash per million gallons. The cost per million gallons has been $3.03 for lime and $11.72 for soda ash, making a total of $14.75. Sulphate of iron and alum have been used occasionally when the water has been turbid and alkaline, but the cost for these coagulants is negligible.

The cost of chemicals as given in the above paragraph, and also the cost of chemicals which are estimated to be necessary to treat the Monongahela River water, has caused some study and agitation since 1908. A report was made to the board of water commissioners in 1912 by Mr. Leo Hudson, consulting engineer, with the coöperation of the writer, and the following quotation is taken directly from the report.

> There are several questions which may be argued in considering the Monongahela River as a source of supply, and we have endeavored to give them all due consideration. The United States government is contemplating making improvements in the Youghiogheny River, and if these improvements are made they will unquestionably affect the condition of the river water, in that after rains the pools will be filled with alkaline water which will neutralize for a short time the acid coming down from the coal mines as the two waters mix together. We believe that these improvements will have a tendency to better the general character of the water; but in times of drought the improvement in the water will not last long enough to make it valuable. It has been stated that on account of the development of new coal mines in the Monongahela Valley, the water in this river is constantly getting worse on account of the increasing acidity of the water, and also on account of the abandonment of mines in the Youghiogheny Valley the tendency would be toward improvement in this river in that the acidity would become less. We feel that this conclusion is true regarding the Monongahela, but not true regarding the Youghiogheny. The abandonment of a mine does not decrease the amount of drainage from it, provided it is a drift mine, and the condition of the water coming from abandoned mines and old gob piles is just as bad, if not worse, than that from an active working. Therefore, we claim that the water in the Monongahela River may get worse, due to increasing acidity, but the water in the Youghiogheny River will not get any better. Furthermore, if the improvements which the government contemplates making in the Youghiogheny River are made, the tendency will be to open more mines in this valley, thereby increasing the amount of mine wastes. We believe that this increase will then be as rapid as any increase which may be made in the Monongahela River Valley, and therefore consider that the improvements proposed by the National Government will not ultimately prove of much value in bettering the quality of the Youghiogheny water. Furthermore the drainage area of the Monongahela is considerably greater than that of the Youghiogheny, and the acidity in this river, due to greater dilution, will always be less than the Youghiogheny for the same amount of mine drainage, and it seems altogether unlikely that the actual quantity of mine water discharged on the Monongahela watershed will much exceed that discharged into the Youghiogheny River for many years to come. We believe that it will be many years before the water in the Monongahela River is as bad as the

Youghiogheny from the standpoint of chemical pollution, and that the money saved by taking the Monongahela supply will be well worth while.

There is at times a discoloration in the Monongahela water due to a vegetable stain from the swamps in the Cheat River Valley. This discoloration, however, occurs in objectionable amounts only occasionally following a local flood in the Cheat Valley, and is not injurious.

The bacterial condition of the Monongahela water is unquestionably a great deal worse than the Youghiogheny, but it is believed that this can be taken care of in an entirely satisfactory manner by coagulation, sedimentation and filtration at the present purification plant. The treatment required for the Monongahela supply is a great deal less, and the finished product will be more uniform and give greater satisfaction than the present supply, which at times requires very heavy treatment. The total estimated cost of this improvement is $70,000, and the estimated saving in cost of chemicals is $15,000 per year.

This report was approved by the city authorities, but no steps were taken to provide funds for the improvement. The general satisfaction with the softened supply was so great that it was considered unwise to make a change which was regarded by some as more or less of an experiment. With the great advance in the price of soda ash during the past year it became apparent that the chemical costs of softening the present raw supply would be more than trebled. The building of this new intake became no longer a matter of good policy, but became an actual necessity, and emergency measures were passed by the City Council providing for the quickest possible execution of the work.

This improvement consists of an intake and low service pumping station along the east shore of the Monongahela River about a mile above the point where the Youghiogheny joins this stream. The pumping units consist of three electrically driven centrifugal pumps of a daily capacity of four, five and six million gallons respectively. From this station the water is to be pumped through a 24-inch cast iron main 10,000 feet long to the present purification plant. The cost of the entire improvement will be about $75,000.

The amount of saving effected will depend to a great extent upon the market price of water works chemicals, especially soda ash. At the normal price of soda ash, which for several years previous to the advance due to war conditions was approximately $14 per ton delivered, it was estimated that $15,000 per year could be saved by this change. Under the contract in force at present soda ash costs $50 per ton, and at this price the saving will amount to $25,000 to $75,000 per year, depending upon the condition of the water in the two rivers.

The additional data secured since 1911 bear out in part the premises taken in the report made in 1912. These data indicate that the Youghiogheny River is not improving in quality, greater extremes of hardness and acidity being noted now than in the past for the same stage of water in the river, which is the only rational method of comparison.

On the other hand the water in the Monongahela River does not appear to be growing worse, and while it is still considered probable that eventually the water in this stream will show greater pollution with acid, it is believed that it will be a great many years before a condition exists which will even approach the present condition of the Youghiogheny. The watershed area at McKeesport is more than three times that of the Youghiogheny, and on account of slack water conditions the flow is much more uniform. There are thirteen dams in the river above McKeesport, and the pools formed act as a series of settling basins where considerable purification takes place due to coagulation and sedimentation. The mine water carrying the sulphates of iron and aluminum mingling with the alkaline water of the stream produces naturally the proper conditions for the process of coagulation, and this process is often very complete, the water in the river having the appearance of the water in the coagulation basin of a mechanical filtration plant. There is ample opportunity for the coagulated material to settle out and this produces interesting color changes in the river; in one part of the river the water is brownish yellow in color from the precipitated iron, and as this begins to settle out greenish splotches and streaks appear, giving to the water a mottled appearance; and finally the river appears perfectly clear, or may have a greenish color if the water is acid and contains much iron in solution.

A glance over the results of the hardness and acidity or alkalinity determinations is sufficient to show the necessity of the change in the water supply. With the data available in 1907, and even in 1911, there was room for a difference of opinion in regard to the advisability of obtaining this new supply; but the records now at hand make the wisdom of the change in the raw water supply apparent, and permit of no difference of opinion as to the advisability and necessity of the step taken.